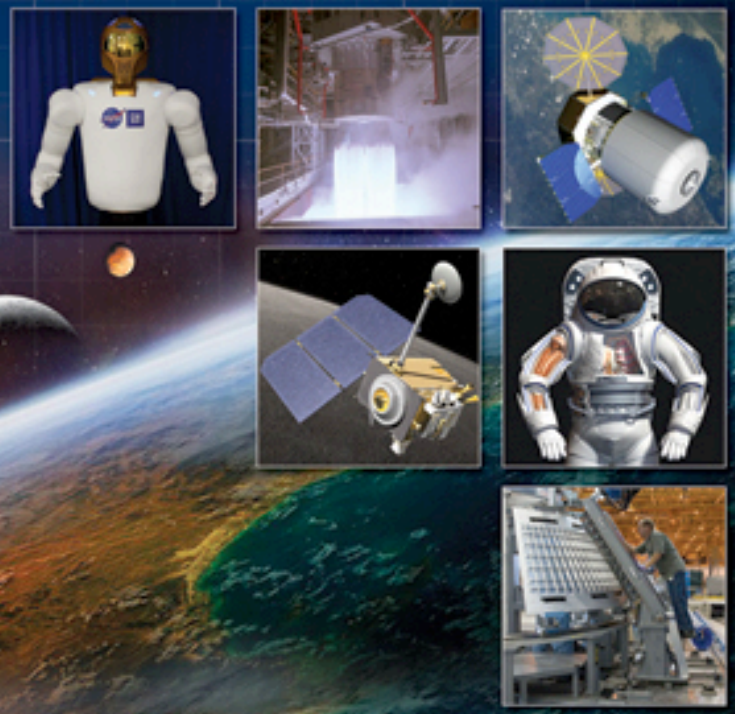
National Aeronautics and Space Administration

Exploration Enterprise Workshop:

FY 2011 Exploration Precursor Robotic Missions (xPRM) Point of Departure Plans



Moody Gardens Conference Center/Hotel
Galveston, TX

May 25, 2010

Disclaimer

This chart set was presented by the Exploration Precursor Robotic Missions (xPRM) study team, on May 25, 2010 at the NASA Exploration Enterprise Workshop held in Galveston, TX. The purpose of this workshop was to present NASA's initial plans for the potential programs announced in the FY2011 Budget Request to industry, academia, and other NASA colleagues. Engaging outside organizations allows NASA to make informed decisions as program objectives and expectations are established.

The presentation begins with a background and context of the importance of precursor missions with regard to human space flight in the past, currently, and how they will be essential to human health and safety in the future. The presentation introduces the content, management, and requirements of the proposed program and how the program will address the priority needs of human space flight. There are several charts that lay out some of the near term notional missions, the first beginning in 2014. The presentation concludes with a chart showing the forward work planned for FY2010.

DISCLAIMER: The following charts represent at "point of departure" which will continue to be refined throughout the summer and the coming years. They capture the results of planning activities as of the May 25, 2010 date, but are in no way meant to represent final plans. In fact, not all proposed missions and investments fit in the budget at this time. They provide a starting point for engagement with outside organizations (international, industry, academia, and other Government Agencies). Any specific launch dates and missions are likely to change to reflect the addition of Orion Emergency Rescue Vehicle, updated priorities, and new information from NASA's space partners.

Background and Context

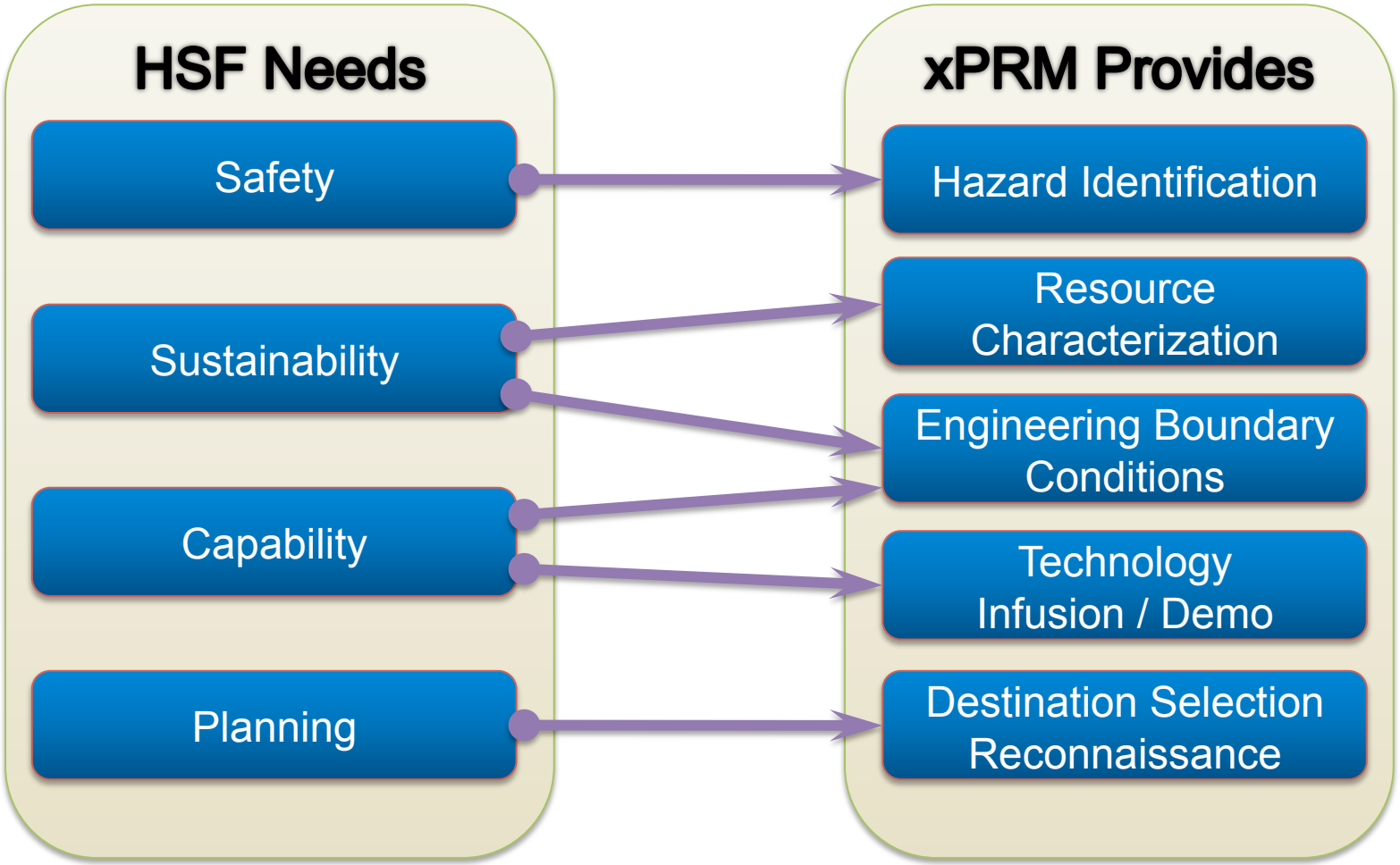
- **Human Exploration precursors were essential to the success of Project Apollo in the late 1960's to early 1970s:**
  - *Robotic precursors such as Surveyors and Lunar Orbiters defined the engineering boundary conditions and environments for human exploration of the Moon, as well as potential hazards*
- **More recently, human exploration precursors have been designed and flown in support of the 2004 National Space Policy Directive 12 Plan:**
  - *LRO and LCROSS are recent/current human exploration robotic precursors designed to provide applied knowledge essential for the safe and cost-effective return of humans to the lunar surface*
- **No matter the human spaceflight destination beyond low Earth orbit (LEO), exploration robotic precursors are essential to ensure human health and safety:**
  - Comments to this effect were made by the Augustine Committee in 2009
  - Exploration Precursor Robotic Missions to future human destinations are particularly important in the decade from 2010 to 2020 to characterize:
    - *Near Earth Objects (NEOs)*
    - *Lunar resources (esp. volatiles)*
    - *Mars orbit and surface (resources, hazards, dust, toxicity)*

Introduction

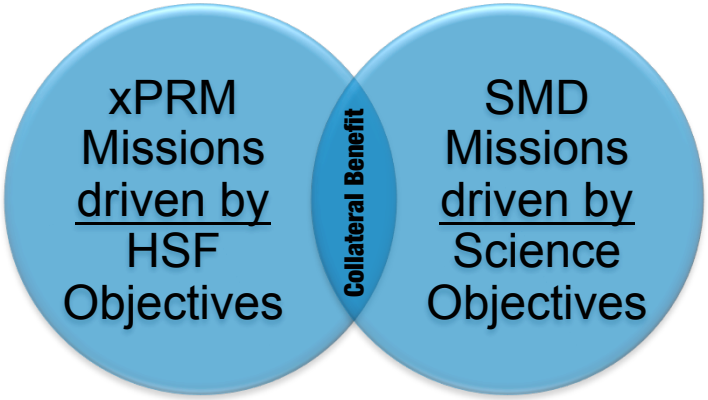
- NASA Planning for FY11 calls for a "*steady stream of **[Exploration] Robotic Precursor** missions*" and related activities:
  - We define this effort as Exploration Precursor Robotic Missions (**xPRM)**
  - The xPRM effort would consist of <u>two Programs</u>:
    - **xPRP**: set of linked flight missions, instrument developments, and R&D for the purpose of acquiring applied precursor knowledge for human spaceflight (HSF)
      - Cost range $500M to $800M (total mission life cycle cost with launch)
    - **xScout**: focused, less-expensive, higher-risk missions, with cost cap of $200M including launch
  - The 2 xPRM Programs would be administered by ESMD with Program Management at NASA field Centers (xPRP at MSFC, xScout at ARC)
  - These proposed program lines include a portfolio of missions in the form of a time-ordered sequence with specific priorities traceable to Program Requirements
  - Specific driving requirements have been generated for the xPRM program by the Study Team as draft Program Level 0 requirements.

Why xPRM? *Enabling HSF proactively…*

- xPRM uniquely and specifically addresses HSF priority needs.



How is xPRM unique from robotic SMD missions?



- Science Mission Directorate (SMD) missions are driven almost entirely by science objectives set by the National Academies Decadal Survey process, and therefore do not typically address high-priority Exploration precursor/HSF objectives
- xPRM missions will be designed to conduct the precursor measurements/experiments to quantitatively inform and support HSF objectives
  - These are different objectives that lead to different activities in many cases
- There are exceptions in both directions
  - Where synergy exists, we will work to take smart advantage of it

Sample Topic: Oxygen content of lunar regolith	
HSF/xPRM Questions:	**SMD/Science Questions:**
Where is it localized and at what form and concentration? Can it be accessed? How to best access and process it into a HSF "resource"?	How does spatial distribution of Oxygen inform the investigations of volatile sources and sinks within the solar system? [includes Oxygen-bearing molecules]

xPRM Top Level Objectives and Principles

- To conduct **precursor measurements/experiments*** in support of human exploration:
  - Quantify the engineering boundary conditions associated with the environments of human exploration beyond LEO.
  - Indentify hazards (to ensure safety)
  - Identify resources (to facilitate sustainability, lower launch mass, and “living off the land”)
  - Provide knowledge to inform the selection of Human Exploration destinations
- To provide a platform for **technology flight demonstrations** which support human exploration.
- To **coordinate** with other NASA directorates.
  - Avoid overlap, identify complementary objectives, leverage dual-use opportunities
- To **foster competition** in mission/payload/investigation selections.
- To foster opportunities for **international collaboration** which benefit human exploration.
- To foster **participatory exploration** opportunities

*An HSF priority **precursor measurement/experiment** is a necessary component of any xPRM mission.

DRAFT xPRM Level 0 Requirements

The xPRM shall:	
1	Develop robotic flight missions to the Moon, near Earth objects, Mars, or to the moons of Mars as a precursor to future human exploration activities.
2	Be comprised of two programs: (i) the Exploration Precursor Robotic Program (xPR) generally consisting of missions costing less than $800M lifecycle cost (LCC); and (ii) the xScout Program generally consisting of missions costing less than $200M LCC.
3	Have a combined average launch rate of one mission every 18 months, with a goal of one every year, commensurate with the availability of adequate funding.
4	Identify and characterize potential human exploration destinations and specific local sites at such destinations by conducting experiments and quantitative measurements relevant to human exploration needs, goals and objectives.
5	Within the xPRM mission portfolio, conduct a lunar surface mission with a near-real-time video imaging capability and a teleoperated mobile element.
6	Quantify hazards associated with potential human exploration destinations including radiation, toxicity, dust, and impediments to safe operations.
7	Infuse flight-ready technologies into systems, provide flight opportunities for technology demonstrations, test operational concepts and capabilities.
8	Conduct a robust research and analysis program element to enable human exploration and gain strategic knowledge about future destinations, the challenges associated with them, quantified risks, and potential solutions.
9	Provide opportunities to engage the public in participatory exploration and offer STEM education activities.
10	Establish partnerships with other NASA Directorates, other agencies and international entities as appropriate to achieve xPRM objectives.

xPRM Programs: xPRP & xScout

- xPRM is a budget line “umbrella” encompassing two proposed (NPR 7120.5) Programs

- **Exploration Precursor Robotic Program (xPRP)** managed by MSFC
  - Flight Missions:
    - Precursor measurements/experiments to enable safe and effective HSF beyond LEO
    - Platforms for technology demonstration
  - Instrument Development (Missions of Opportunity)
    - Enhance investigation opportunities and promote partnerships
    - Fly on non-xPRP missions
  - Research and Analysis for Exploration
    - Turn data into Strategic Knowledge for Exploration
      - Engineering Information, Visualization, Dissemination

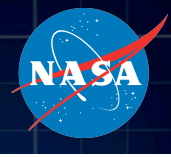
- **Exploration Scouts (xScouts)** managed by ARC:
  - Small ($100M -$200M incl access to space), higher-risk missions
  - Planned to complement and augment xPRP portfolio

xPRM: Flight Mission & Instruments

- **Flight Missions**
  - Medium-sized, strategic missions (generally <$800M incl launch vehicle) with directed project management
  - LRO model – comprehensive investigations (Announcement of Opportunity (AO) competed payloads)

- **Flight instrument** builds for **non-xPRP missions**
  - Missions of Opportunity (MOOs) offer ideal for partnership building with Internationals and other Agencies, or with SMD
  - Instruments will generally be competed with approximately annual SALMON-like call or perhaps in partnership with SALMON (SMD's Stand Alone Missions of Opportunity)

xPRP Element: Research and Analysis for Exploration



- Exploration Mapping & Modeling Project (xMMP)
  - Based on Lunar Mapping & Modeling Project (LMMP) **value-added data reduction/ integration/display** activities
  - Extended beyond the Moon (would include Mars, NEO's)
- Data Systems
  - Contribution for **Planetary Data System (PDS) storage of Exploration datasets**
  - May require new ESMD/SMD agreement as xPRM gets up and running since SMD currently has total responsibility for the PDS.
- Institute/Workshops
  - Recast NASA Lunar Science Institute to **broader Exploration needs** or start new institute.
  - Specialty Exploration **destination-oriented workshops**
- Sensor Tech Development
  - **Not the same** as Instrument Flight Development
  - Technology development for **HSF-driven instruments** *not in Exploration Technology Development and Demonstration (ETDD)* purview (specialized)
- Research Investigations
  - Grants (for non hardware R&D)
  - Modeled after Research Opportunities in the Space and Earth Sciences (ROSES) annual call within SMD
  - Provides **foundational knowledge** needed to interpret mission results and inform the planning of future missions

xScout Program

- Principal Investigator (PI)-led or small, common approach to reduce costs
- Higher risk, more focused investigations
- Assume 18-24 mo cadence
- Co-manifest with xPRP missions where practical
- First launch 2014
  - Stretch: Goal of 2013 launch readiness (requires dedicated launch)
- Budgeting $100-$200 M per mission
  - Includes approx. $50M for access to space (e.g.: Dual-Payload Attachment Fitting, co-manifest or small Expendable Launch Vehicle)

- **Mission content**:
  - Focused scope in support of HSF objectives:
    - Could be threshold measurements or existence-proof experiments
  - xScout AOs written to complement xPRP portfolio with the goal of accomplishing common xPRM objectives

2014: NEO Exploration Rendezvous Orbiter (NERO)

- Discovery-class, with scope similar to NEAR-Shoemaker (rendezvous and close proximity conops with end-game “touchdown”) but geared toward HSF objectives:
  - Hazards, Prox-Ops, Quantify engineering boundary conditions, Resources
- Measurements (potential candidates):
  - Sub-meter-per-pixel imaging in multiple colors
  - Geodetic imaging lidar altimetry (topography)
  - Compositional mapping via multiple approaches,
    - Gamma-ray/Neutron Spectrometry (GRNS) best if low altitude orbit can be established for months, or hyperspectral spectroscopy (0.4 to 5 um)
  - Small sounding-imaging-radar or long-wavelength sounder
- 2014 launch with results in 2015/16, would be in time to influence engineering concepts for HSF to NEO class missions in 2025
- Launch may permit co-manifest opportunity with first xScout
- Option:
  - Investigating feasibility of modifying early xPRM portfolio to investigate several NEO targets early

NOTIONAL Point of Departure – Subject to Change

2015: Teleoperated Lunar Lander

- Target (via LRO information): Sunlit polar region (<100h night) with Earth visibility and confirmed Hydrogen enhancement signature
- Objectives: Resources (including volatiles), hazards (including dust, trafficability and radiation), con-ops (teleops, hi-bandwidth comm and surface mobility)
- Static Lander instruments (possible candidates)
  - 3D-high-definition, wide-field, zoom camera with video frame rate (0.2 frames/second)
  - Dynamic albedo neutron spectrometer with active Neutron source
    - Measuring hydrogen in water down to 1 m depth
  - Volatile mass spectrometer
  - In situ radiation experiment
  - In Situ Resource Utilization (ISRU) sub-system demonstrator
  - Sampling arm possibly with microscopic imager
  - Allotment for partnering experiments
- Surface mobility experiment : Sojourner class “rover” at < 35kg with 1-2 instruments (2kg)
  - Context camera, Dust particle size analyzer, Alpha Particle X-ray Spectrometer
  - Fetch capability

- Lander requires Direct–to-Earth telecom system for near-real time video and playback of all data (unless orbiting relay otherwise provided)
- Lifetime would be more than 2 months (goal of 1 year)

- Impact of design to cost being assessed; Aggressive scope for the budget allocation.

NOTIONAL Point of Departure – Subject to Change

2016: Mars Orbiter

- **Favored Option**: Mars Resource Explorer with Operational Aerocapture
  - Aerocapture critical to mission success, but much more valuable than a smaller fly-along demo.
    - Could perhaps restructure as separate aerocapture demo (though early estimates suggest this option is too expensive)
  - Payload notional Resource Mapping Focus, but likely to be existing or heritage derived designs that could include:
    - Collimated neutron spectrometer
    - Orbital radiation experiment
    - P-band polarimetric synthetic aperture radar with a wide bandwidth
    - Hyper-resolution imaging (5-7 cm/pixel) for landing engineering boundary conditions
    - Possible option: An optical telecommunications demo

- **Option**: Mars Atmosphere/Dust Sample return with Aerocapture Elements
  - Skim the Mars atmosphere for gas/dust sample for direct return to Earth

NOTIONAL Point of Departure – Subject to Change

2018: Mars Lander

- 2018 geometry offers about 3X the mass to Mars as 2016 launch window
  - **Should consider this a priority opportunity for Mars**
    - Several items in discussion, but not at consensus yet.
  - Best options involve landed experiments perhaps in partnership with NASA-ESA program (and planned 2018 content)
  - Possibility of addressing many of the critical National Research Council's "Safe on Mars" issues associated with human landed access to Mars (including Plan. Protection) as well as ISRU experiments
  - Initial cut is Mars Exploration Rover (MER)-class rover with HSF-derived resource investigations
    - Will assess state of the art for Entry. Descent, and Landing (EDL) technology to inform decision.

NOTIONAL Point of Departure – Subject to Change

2019: NEO TBD Mission

- Little Definition to date:
  - Later mission requires less definition at this time
  - Objectives Definition Team (ODT)-process against refined HSF objectives will be used

- Implementation Options in discussion:
  - Discovery/New Frontiers-Class observation platform rendezvous
  - Pair of ESPA-derived prop systems with a “to be defined” instrumentation package to separate targets
    - Separate targets may be attainable with chemical prop by lunar fly-by redirection or by near Earth phasing orbit.
  - 3 to 6 spacecraft in single launch “shotgun” with small instrumentation package and solar electric propulsion systems to separate targets

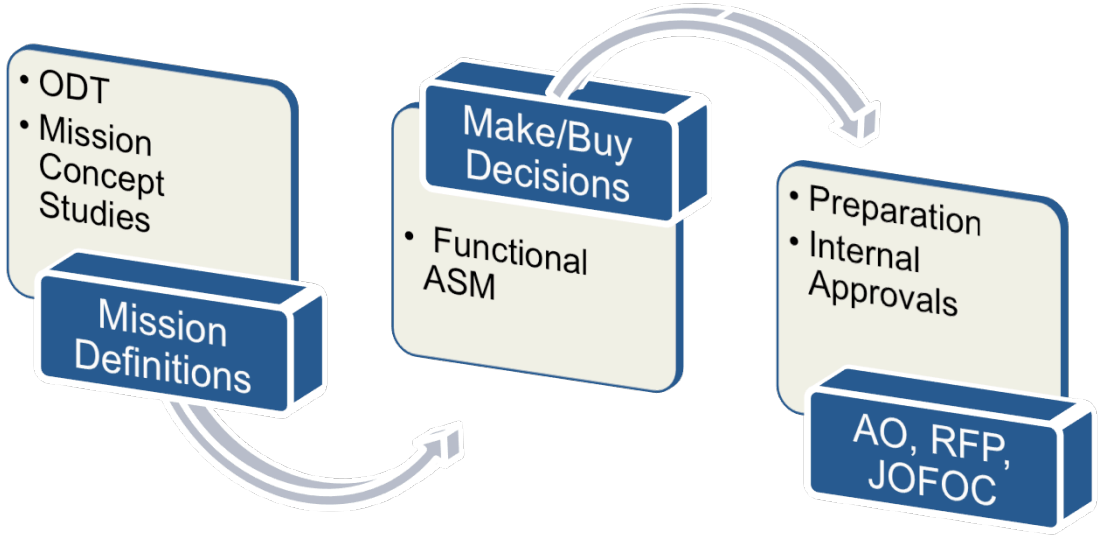
- Investigation Options under discussion
  - Proximity remote sensing, beacon placement, small hoppers, touch & go, grappling, sample return (especially relevant to resources)

NOTIONAL Point of Departure – Subject to Change

FY10 Activities

- In order to complete the intended timeline of missions on the intended schedule:
  - Definition of Mission Concepts and Measurements/Experiments (with feasibility assessments)
  - Payload Make/Buy Decisions (in-house, AO, RFP, build-to-print, etc.)
  - Procurement mechanism preparations and internal approvals

…would need to occur in FY10



Summary

- xPRM would be uniquely poised to provide critical Strategic Knowledge for Exploration from a diverse set of destinations.
  - xPR Missions starting in this decade would enable Human Exploration in the next.
    - Analogous to robotic Surveyor landers ahead of Apollo human missions
  - Proposed scope uniquely focuses on HSF objectives while leveraging unique capabilities of partners.
    - No other program would fulfill this objective .
  - Fully consistent with current best estimate objectives for future HSF at NASA.

POD:	2014	2015	2016	2017	2018	2019
xPRP	NEO Rendezvous 	Lunar Lander 	Mars Orbiter 		Mars Lander 	NEO Rendezvous 
MOOs	MOO1	MOO2	MOO3	MOO4	MOO5	MOO6
xScouts	xS1		xS2		xS3	

NOTIONAL Point of Departure – Subject to Change